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# Report on an Investigation of Underwater Television for Mine Hunting

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## Introduction

This report covers work done on design and test of a television component of mine countermeasure systems between the winter of 1952-53 and the end of the summer of 1953.

Search sweeping for aircraft-laid mines divides naturally into the following divisions: (1) tracking the aircraft, (2) splash spotting, (3) navigation to splash, (4) precise location, (5) identification, and (6) neutralization. Aircraft tracking and splash spotting concern the radar, photographic and visual spotting groups. Navigation to the splash point is of vital interest not only to the television (TV) group but to all of the precise location groups. Precise location was considered to be in the province of the sonar, magnetic detectors, or electric discontinuity detector (EDD). At the inception of the TV project it was specified that TV was to be involved only with identification.

## Proposed Use of TV

A typical operation was supposed to proceed in the following manner. The radar or visual groups were to spot the splash. Then a precise locator (sonar, magnetic detector, or EDD was to be navigated to the splash point either by visual means or radar. The precise locator would have to search a circle of about 200 foot diameter. When a contact was obtained, the precise locator would drop a buoy at the contact point. Then the TV gear would

move to search an even more limited circle of about 10 foot radius. If a buoy could not be placed at the contact point, (as is the case with sonar) then the TV gear would carry a corner reflector on the camera. The sonar boat would stand off a short distance, maintaining both the contact with the mine and with the TV apparatus. Then the sonar boat could guide the TV equipment to the point of contact. After the mine was located and identified, the neutralization team could perform its function, either raising, disarming, or destroying the mine.

## Description of Available Equipment

The television project began with the goal of completing a working unit in about three or four months in order to start operations in the summer of 1953. Table I gives a comparison of some specifications on the two types of commercial equipment available.

TABLE I

Comparison of Cameras

| | Vidicon | Image Orthicon |
|---|---|---|
| Sensitivity | 0.2 amp/foot candle | 150 amp/foot candle |
| Resolution | about 350 lines | better than 500 lines |
| Cost including cable | $6500 | $20,000 |
| Delivery | 4 weeks | 8 to 9 months |

While the Image Orthicon is technically the most desirable, the time element forced us to the Vidicon chain. If the project

were to continue here, work with the Image Orthicon would be the next step.

Mine damage ceases to be significant if the mine is laid in water greater than 200 ft. deep. This 200 foot requirement gives both the cable length and strength of housing required for TV use. The housing is a simple cylinder with a lucite window in the front; the back circular plate is bolted to the cylinder, the water-tight joint being an O-ring. The camera is mounted on the back plate. The camera cable enters the back plate through a short close fitting pipe. The seal between cable and pipe is made by rubber tape. This simple housing and cable seal have been completely satisfactory.

The Vidicon chain is the RCA ITV-5 (Industrial Television Model 5). This chain incorporates a remote camera focus but no iris control. The focus is obtained by moving the lens relative to the Vidicon tube, which is fixed in position. In order to get an iris control to this type of set up, it would be necessary to have an iris control motor which would be mounted on the lens. Or, alternatively, some type of gear drive which would disengage when the lens was moving.

The problem is simpler if the lens is fixed, for then the iris control motor is directly coupled to the lens. The camera is mounted on a brass slide and is driven by a lead screw powered

by the focus motor.

This iris control and camera mounting are shown in Figure 1.

## Lens

With the viewing distance restricted by scattering and turbidity, we need a wide angle lens to cover the greatest bottom area. At the beginning of the project, the widest angle lens we could find was Elgeet 13-mm. f/1.5.

At Panama City on 3-6 August 1953, tests which we attended were being run with a new type plastic wide angle lens. This lens, manufactured by the Pacific Optical Co., has an angle of view of 162°. The tests at Panama City used an Image Orthicon camera. The front of the camera housing was a large plastic dome so that it would not constrict the viewing angle of this lens.

However, our equipment was already built, and such an alteration would have taken too much time. We ascertained by telephone that sea water would not damage this lens. We then mounted the lens outside the housing (see Figure 2). The 2-inch Wollensak lens is mounted on the camera and views the wide angle lens through the plastic window. The remote focusing is still possible.

## Lighting

Two types of artificial lighting were used during the course of the summer's work:

1) 1 kw tungsten filament marine lamps supplied by Morse Diving Equipment, Boston, Massachusetts.

2) General Electric AH-6 mercury arc lamps (1 kw).

The lamps were mounted on the base corners of a pipe tetrahedron; the camera housing occupied the vertex. The mounting arrangement with the tungsten lamps in position is shown in Figure 3.

The two types of light differ mainly in the spectral distribution of the light output. Table 2 shows this distribution roughly.

TABLE II

PerCent of Overall Input Power Radiated in Different Spectral Ranges

| Wavelength in Ångströms | AH6HgARC in Pyrex Glass Water Jacket | Tungsten Filament 900 Watt |
|---|---|---|
| Less than 3165 | 0.42% | 0.00% |
| 3165 - 3800 | 5.3 | 0.13 |
| 3800 - 5000 | 12.1 | 1.8 |
| 5000 - 6000 | 8.5 | 3.7 |
| 6000 - 7600 | 3.0 | 9.8 |
| Above 7600 | 6.1 | 74 |
| Total % of Input Power Radiated | 35.4% | 89.4% |

(Data from GE Company, GET--1248--C)

Most of the radiation from the tungsten filament lamp is further to the red than the spectral response peak of the Vidicon tube. On the other hand, the mercury arc lamp output power peaks in the region of best response of the Vidicon. Therefore, it seems that the mercury arc lamp will provide far better illumination than will an equal power tungsten filament lamp. Operations were carried out with both types of illumination, and it was found that the mercury arc lamps did provide a much better source of light. Much more detail was visible with the mercury arc lamps than with the marine lamps.

The most direct comparison of the value of the two types of lamps was made at night. With the three marine (tungsten filament) lamps mounted in the reflectors and turned on, one mercury arc lamp, mounted in a simple semi-cylindrical aluminum reflector on the tetrahedron base, was turned on. This greatly increased the visibility. The mercury arc lamp was now kept on, and the three marine lamps were turned off. This resulted in almost no decrease in vivibility. Similarly, in daytime operations the marine lamps seldom improved visibility much over natural light alone, while the mercury arc lamps resulted in much more detail being visible. The mercury arc lamps were clearly superior to the marine lamps, but variations in water conditions made it impossible to get any accurate comparison of the two sources.

Although the mercury arc lamp showed a definite superiority in lighting effectiveness over the marine tungsten filament lamp, it has the disadvantage of a much shorter life. The major problem is proper cooling for the lamp. At first the mercy arc lamps were cooled simply by being placed underwater, but the lamps burned out almost immediately. Mr. Ralph Farnham of the G.E. Company advised us that this was caused by the formation of steam bubbles on the quartz tubing resulting in high local temperatures and cracking. He pointed out the necessity of circulating water past the lamps to remove the bubbles forcibly. Glass envelopes were made and a 6 volt submersible pump was used to force sea water through these envelopes at about 4 quarts per minute. The pump mounted on the tetrahedron is shown in the lower left corner of Figure 3.

With the additional cooling, the lamps lasted longer, with some lifetimes as high as 20 hours. Further work on the mercury arc lamps is continuing at the David Taylor Model Basin.

## Operations

### 1. Preliminary Operations

The project was able to make preliminary investigations of the problem with an ITV-2 chain, which was loaned by the David Taylor Model Basin. The results obtained at that time amounted to an outline of the problem. These important points were to be seen in more detail later: (1) the desirability of a lens giving a wide field of view, (2) the lighting problem,

and (3) the problem of navigation and general handling of the equipment on a small boat.

The boat on which the equipment was mounted was the OTIS, a 40-foot former fishing vessel. During these preliminary operations the poor maneuverability and general behavior of the OTIS made the outlook for the summer look pessimistic. However, an optimistic side was presented by the ability of the ITV-2, with illumination, to distinguish bottom detail at depths of fifty feet.

2. Operations with the ITV-5

A. General remarks.

The operations in general fell into two categories: (1) those in which an object suspended from the boat, and whose position with respect to the field of view (of the TV) was controllable, was viewed, and (2) those in which objects on the bottom (or the bottom itself) were viewed. Of course, the second of the foregoing categories is the one to be encountered in practice.

The housing for the TV camera was mounted at the center of a pipe tetrahedron, the camera pointing downwards. Illumination was provided from the three apices at the base of the tetrahedron. The whole arrangement was suspended by a wire rope which passed through a pulley on the boom of the OTIS, and which could be wound up by a winch on the deck. Cables ran from the

housing and the lamps to equipment below deck (in the engine room) (see Figure 4).

B. Tests with disc.

A brass disc, imprinted with a geometrical design, was lowered into the illuminated region, to depths as great as the bottom. It could easily be seen and recognized by the TV while in the illuminated region, at distances up to 10 feet from the lens. However, it was not recognizable outside the field of illumination. In this particular test illumination was provided by two marine tungsten lamps (1000 watts each).

C. Tests with other objects.

Successful operations were carried out with two other types of object. First, an aluminum sphere was lowered to a depth of 30 feet, and photos were taken of the vidicon screen. Figure 5 shows one of those photos. Another group of objects, whose positions were inexactly known, was a group of metallic spools (light frame construction, 2 feet in diameter). In spite of some difficulty in navigation, they were found, and a photograph was taken, shown in Figure 6.

D. Operation in conjunction with other groups.

It happened that a shipwreck had been discovered (by a sonar system, with verification by divers), and such an object was thought to be of sufficient size so that the navigation problem of the OTIS would be minimized. Several days after the original contacts, the sonar boat returned to the location

(guided by radar) and dropped a buoy 150 yards east of the contact point. This information was communicated by radio, enabling the TV boat to proceed to the approximate location of the wreck. A buoy was then dropped by the TV boat for reference, and after a short time the wreck was located about 10 yards from the buoy. Various details of the wreck, such as ribs, could be seen, even without illumination.

E. Attempts to view mines.

Several hours were spent with the speific intention of viewing one of the mines which lay on the bottom. The lack of success in this respect is attributed to the difficulty in navigation. If the equipment had been over a mine, it would have seen it, as it was always possible to observe detail on the bottom.

## Conclusions

1. The summer's operations indicate that water as a medium of transmission offers no great hindrance to the use of television for short ranges.

2. The principal difficulty inherent in a crude underwater TV system is the problem of controlling the position of the camera.

3. The lighting problem is second in importance only to the control problem, at least with a vidicon camera.

4. The control problem must be considered from two aspects, (1) the simple and efficient control of the camera with respect to the boat, and (2) the navigation of the boat with respect to objects being viewed or searched for.

5. It is thought that a sweep width of 10 feet should be easily obtainable with presently available equipment and an adequate mounting.

## Recommendations

If and when further work on underwater television is contemplated, the following points should be considered.

1. The use of an Image Orthicon camera should be investigated, as this should greatly reduce the lighting problem.

2. The development of some sort of more reliable mercury arc lamp would be desirable.

3. The navigation problem should be thoroughly investigated, both with respect to the most efficient use of existing boats, and with respect to the possibility of developing a new type of boat, such as a controllable raft. Persons skilled in the handling of small boats may be of considerable assistance, although the particular problem seems to be one which is never encountered in small boat operation.

4. The solution of the control problem may require the use

of several cameras in an array, so that as a whole they would cover a particular field of view. Such an arrangement might be fruitfully investigated.

* * *

The author wishes to acknowledge the assistance of W. Rall, B. Beeken, and R.E. Barrett who helped in planning and carrying out these tests.

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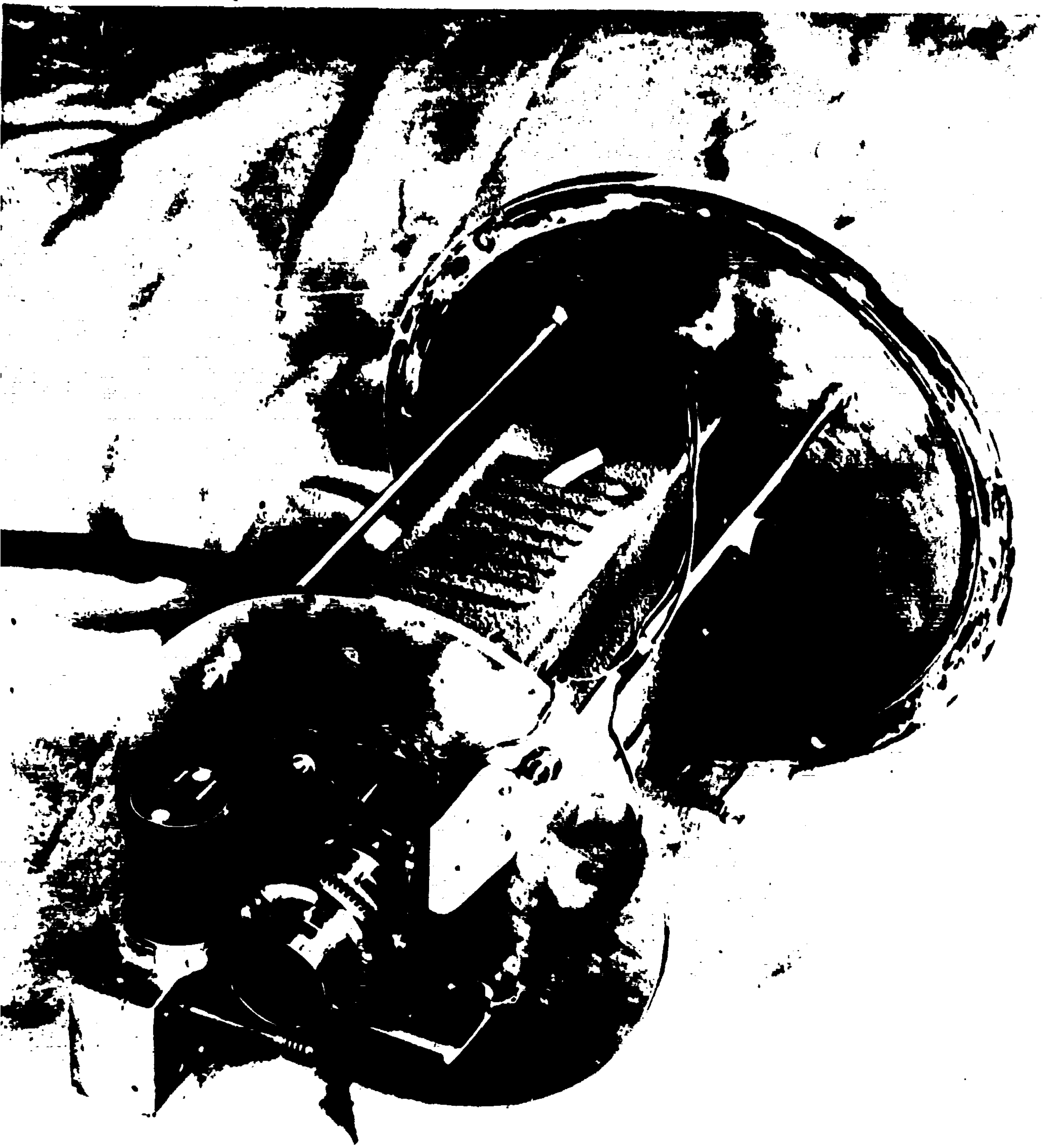

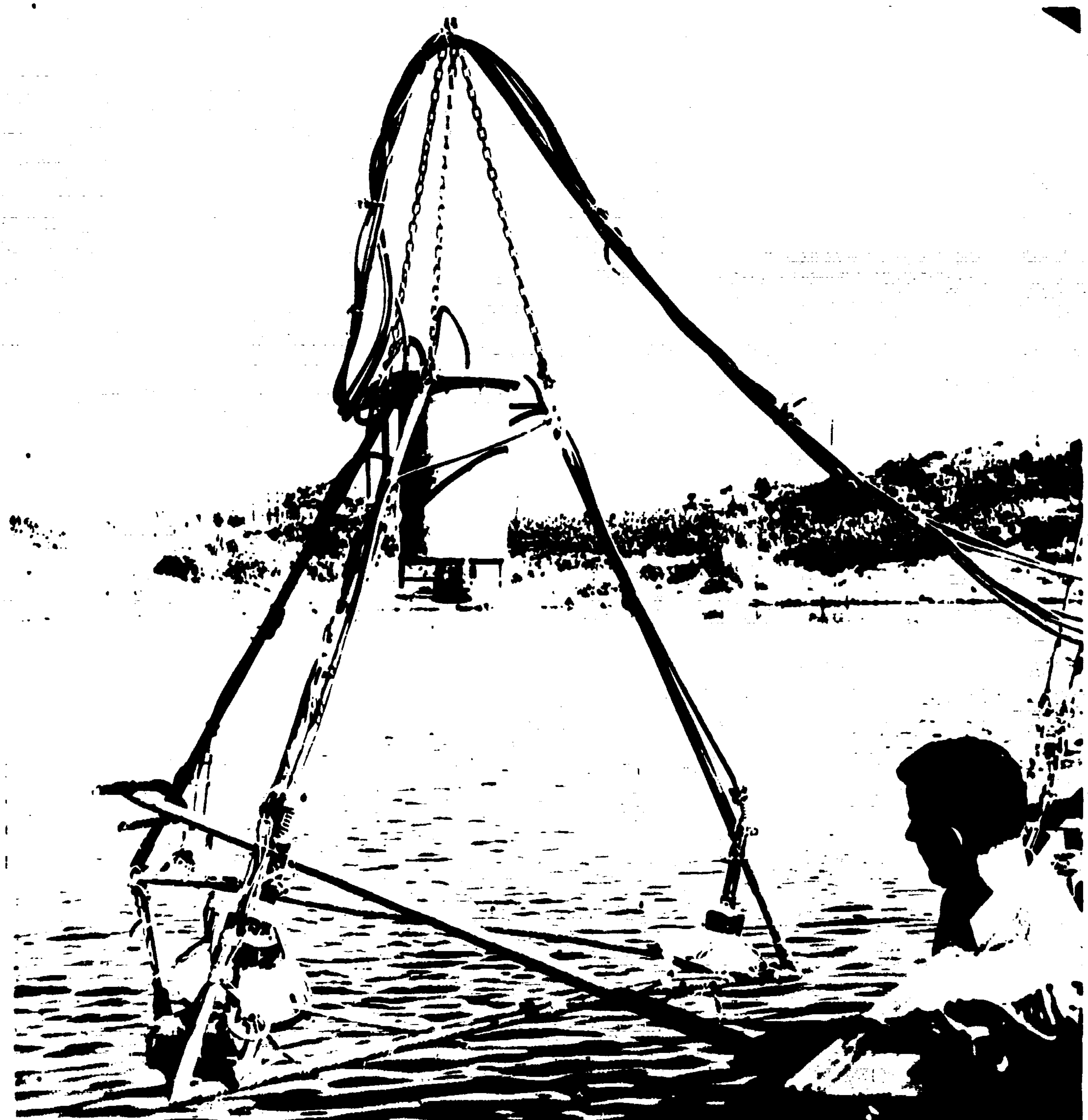

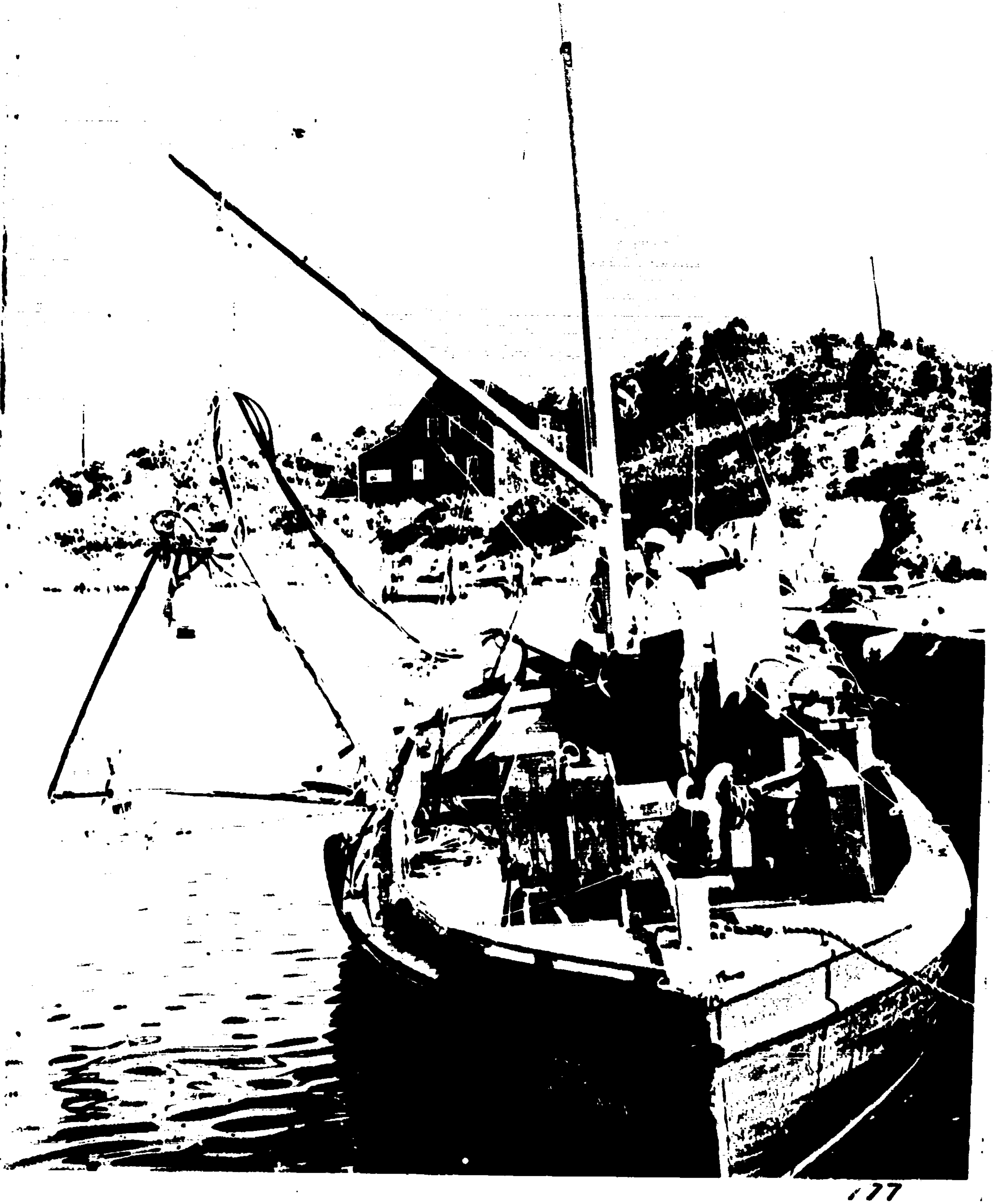

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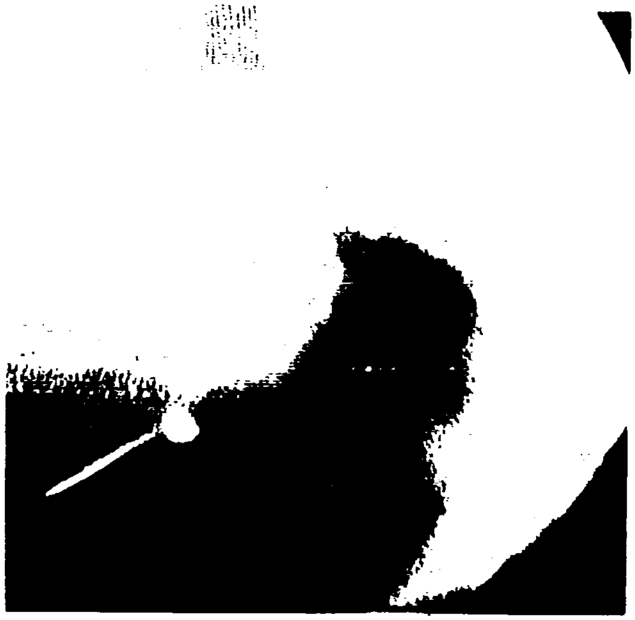

ALUMINUM SPHERE ON BOTTOM (30 FOOT DEPTH)

FIG. 5

TWO-FOOT SPOOL ON BOTTOM

FIG. 6